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Turning Characteristics of Tracked Vehicle on Fresh Concrete

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Research objective:

The objective of the research is to establish numerical analysis to predict turning characteristics of tracked vehicles. Especial attention was paid to vehicle running on weak terrain where the sinkage of the vehicle is relatively large. In this report, the turning characteristics of tracked vehicle running on fresh concrete will be reported based on results of numerical analysis and experiment.

Numerical analysis and experimental conditions:

The numerical analysis is established based on a numerical method to solve a set of non-linear equations describing steady turning state of tracked vehicle [1]. The unknowns of the set of equations are to-be-predicted turning characteristics. These characteristics include static and slip sinkage distribution, track tension distribution, pressure distribution, longitudinal, lateral shear resistance distribution, turning radius, slip ratios of each track, eccentricities of ground reaction force, turning moment and forces acting to turning tracked vehicle. From the above mentioned unknown characteristics the group of 5 basic independent unknown characteristics could be established. These characteristics are sinkage of front idler and rear sprocket of one track (either outer or inner), lateral trim angle, slip ratio of the inner and outer track. Other unknown characteristics can be calculated from the above 5 independent unknown characteristics using basic terra-mechanical relationship such as Janosi-Hanamotor's equations, Bekker's pressure sinkage relationship and other geometrical relationships. The problem can then be expressed as which combination of vehicle position (specified by sinkage of front idler and rear sprocket of one track and lateral trim angle) and running condition (specified by slip ratio of outer and inner track) would satisfy 5 equilibrium equations. Solving this set of 5 equilibrium equations for 5 above mentioned independent unknowns solves the problem. The set of equations is solved based on Newton-Raphson method [2].

Vehicle weight (N) W	638
Height of hitch point (cm) H_{dp}	15
Dist. from grav.cent. to hitch point(cm) L_{dp}	30
Initial tract tension (N) Ho	196
Height of gravity center (cm) Hg	10
Contact length (cm) D	33
Track width (cm) B	10
Track gauge (cm) C	23
Grouser height (cm) H	1.7
Grouser pitch (cm)	2.55
Grouser thickness (cm)	0.3
Maximum track extension (cm)	1
Rad. of front idler (cm) R_f R_r	6.5
Radius of road rollers (cm) R_m	1.9
Number of road rollers	3
Road roller interval (cm)	6

Table 1 Vehicle specifications

k_1 (kgf/cm$^{n1+2)}$	0.023	m_{clon}(kgf/cm^2)	0.002
n_1	1.213	m_{flon}	1.017
k_2 (kgf/cm^{n1+2})	0.871	a_{lon}(cm)	0.153
n_2	0.801	m_{clat}(kgf/cm^2)	0.013
c_0(cm$^{1+2c1-c2}$/kgf^{c1})	7.485	m_{flon}	1.017
c_1	0.915	a_{lat}(cm)	0.123
c_2	0.601		

Table 2 Terrain-track system constants

The equations are established based on various assumptions. The vehicle is considered to be in steady turning state, or in other word, in a turning motion with constant velocity. With this assumption the vehicle is turned in a circular path. The turning pole of the vehicle is considered to be in the longitudinal centerline of vehicle and at the center of the ground reaction force. Turning moment was considered to overcome lateral shear resistance and lateral bulldozing resistance. The lateral shear resistance was computed based on a consideration to determine lateral amount of slippage [1]. The pressure is considered to be uniformly distributed in lateral direction and centrifugal force was ignored.

The simulation was applied for a model vehicle turning on fresh concrete. The experiment was carried out to verify the simulation. The input to the simulation is the vehicle design characteristics and its running conditions. Table 1 shows dimension of the model vehicle as an input to the simulation. Running conditions are characterized by terrain-track system constants, steering ratio (defined as ratio of circumferential speed of outer and inner track), value of effective tractive effort and its traction angle. Table 2 shows terrain-track system constants for the given vehicle and fresh concrete of slump of 55 cm as the input to the simulation. The vehicle is the scaled model of a bulldozer and is driven by two electric motors through chain transmission. The rotary speed of the main shaft of the motors can be set at a

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fixed value through speed regulator. The vehicle is turned with steering ratio of 2.2. It has a rigid suspension system and three road rollers support each of its tracks. The experiment was carried with effective tractive effort of 0, 69 and 147 N. The traction angle was zero for all the cases of effective tractive effort. The measured values are sinkage of front idler, rear sprocket of both tracks, slip ratios and turning radius.

Numerical and experimental results:

Fig. 1 shows the comparison between measured and calculated values of sinkage of front idler for different effective tractive effort. Fig 2 shows the same comparison for rear sprocket. The values of the sinkage in the figures are the sinkage of the beginning and end point of the track theoretical contact length and at the centerline of each track.

Fig. 3 and 4 shows the comparison between measured and calculated slip ratios i_o and i_i of both tracks and turning radius respectively for different effective tractive effort. The slip ratios are the values at the centerline of each track.

Figures show that good match can be observed between measured and calculated values. The experiment could be carried out only for 3 cases of effective tractive effort due to technical difficulty on keeping constant effective tractive effort at traction angle of zero. With the assumption that the turning pole of the vehicle is in the longitudinal centerline of the vehicle and at the center of ground reaction force the turning radius (radius of circular path of turning pole) become larger with larger effective tractive effort (at zero traction angle).

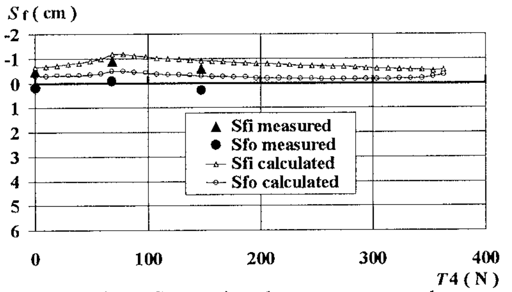

Fig. 1 Comparison between measured and calculated sinkage S_f of front idlers relating to effective tractive effort $T4$

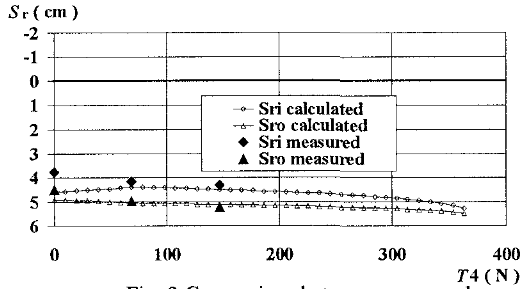

Fig. 2 Comparison between measured and calculated sinkage S_r of rear sprocket relating to effective tractive effort $T4$

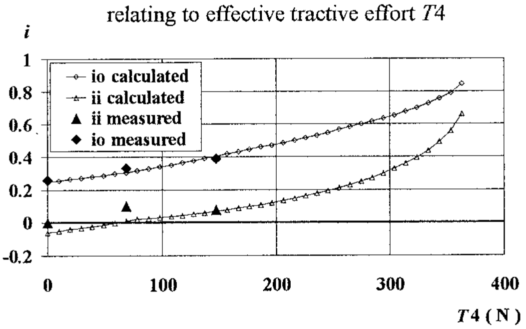

Fig. 3 Comparison between measured and calculated slip ratio i relating to effective tractive effort $T4$

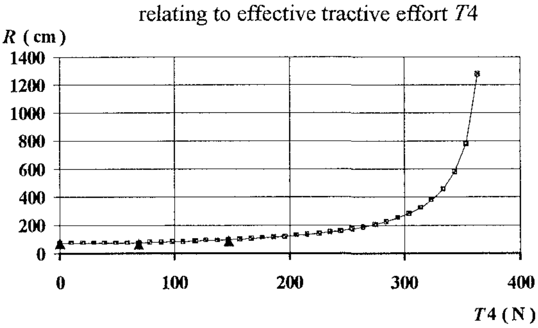

Fig. 4 Comparison between measured and calculated turning radius R relating to effective tractive effort $T4$

Conclusion:

The simulation analysis was established and applied for a model of rigid suspension tracked vehicle turning on fresh concrete. The experiment was also carried out and the results were compared. The comparison shows that the simulation has high accuracy and can be used to predict turning characteristics of tracked vehicle or to analyze the effect of design characteristics to turning characteristics of tracked vehicle.

References:

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2) William H. Press, Saul A. Teukoisky, William T. Vetterling, Brian P. Flannery, Numerical Recipes in C, the art of scientific computing- second edition, Cambridge Univeristy Press pp 379-393, 1995.